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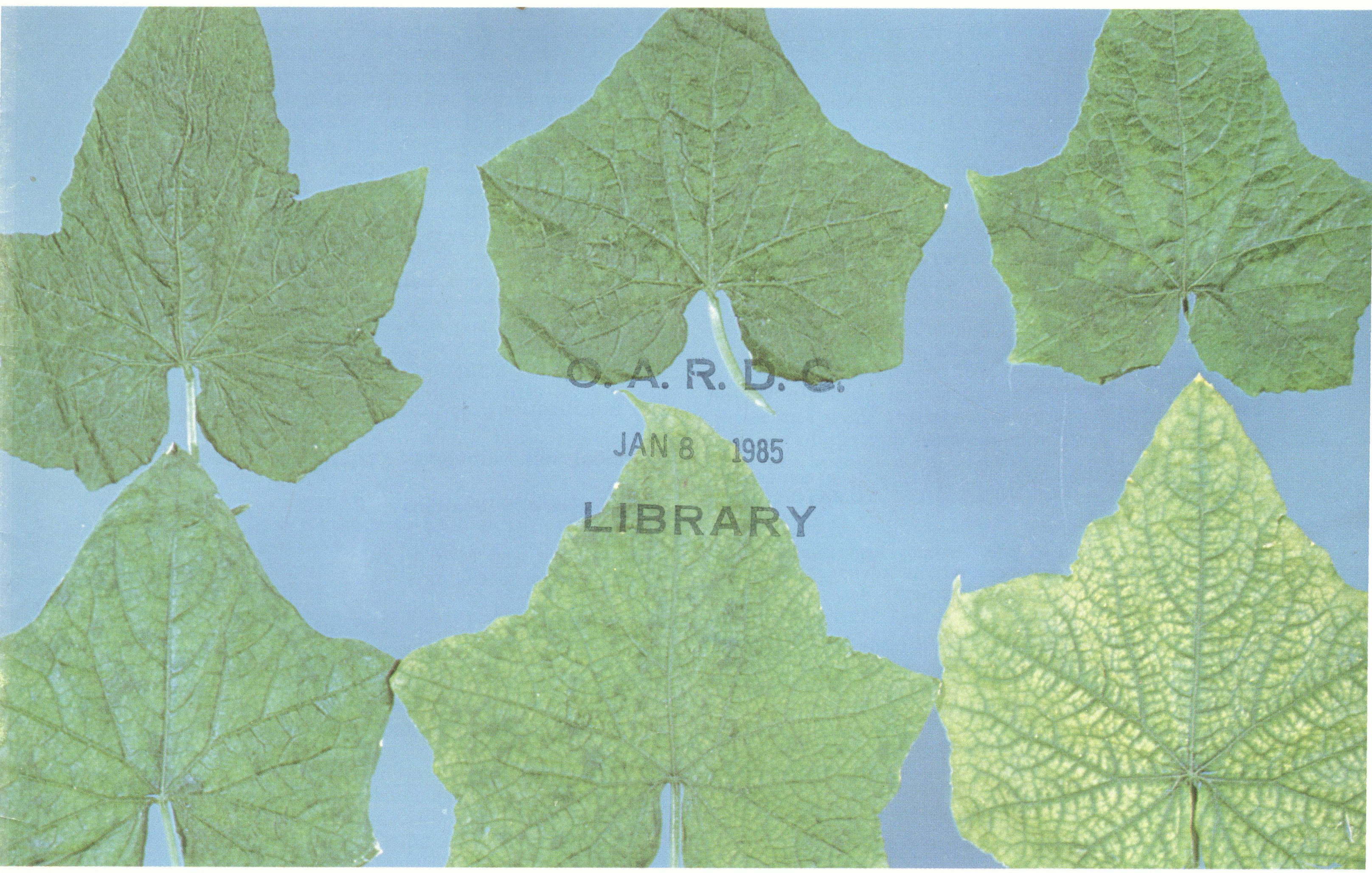
GREENHOUSE CUCUMBERS

DISEASE AND INSECT CONTROL



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Cover photo: Progression of Beet Pseudoyellows Virus symptoms from initial mottling (upper left) to advanced chlorosis (lower right).

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CONTENTS

GREENHOUSE CUCUMBERS
Disease and Insect Control

NOTE: Figures discussed in text are located on pages 8 and 9.

Growing vegetable crops in greenhouses or other protected situations does not mean these crops will not be attacked by pathogens, insects or mites. In fact, pest damage often can be more severe than it is on outdoor crops. High plant densities, continuous cropping systems, warm temperatures and frequent plant handling, all contribute to the severity of pest attacks.

Identification and control measures available for common insect and disease problems of greenhouse cucumbers are discussed in this bulletin. Although disease and insect problems that regularly occur on European seedless cucumbers grown in Ohio are emphasized, **growers from other regions will find this information useful.** Pesticide recommendations are not given here. Ohio growers should get a copy of Cooperative Extension Service Bulletin 517 for the latest information on chemical and biological control. Growers in other states should consult with their state authorities.

SANITATION

Greenhouse growers have the opportunity to use many nonchemical methods to limit pest development. Some of the most important ones are grouped under the heading of sanitation. Sanitation options available to a grower are limited only by his imagination and understanding of the pest organisms he is attempting to control.

Growers are urged to approach sanitation with three goals in mind: 1) prevent the introduction of pest organisms, 2) eradicate pest organisms or severely limit their populations, and 3) reduce the spread of pest organisms.

Important considerations for a good sanitary program in a commercial greenhouse include proper disposal of crop refuse, adequate soil sterilization, disease-free seed, clean pots and potting soil, clean tools, clean clothes for workers, and prevention of the transmission of pests on the hands of workers. Points to consider outside the greenhouse include maintaining a clean strip around the greenhouse, keeping crops that harbor cucumber pests away from greenhouses and eliminating weeds from around greenhouses.

Beginning with crop termination, let's review the principles of sanitation and provide some working examples.

Crop Removal

Remove the old crop and any weeds that have grown between crop rows or around the edges of the greenhouse. This includes the root system, fruit and leaves. Complete removal of all plant parts will make later sanitation steps more successful. Old plants must be disposed of properly. The best method is to transport them to a nearby landfill for burial. **Do not pile them on your property near the greenhouse.** Pests can spread from these "dump" piles into the greenhouse. Some Ohio and Canada growers have found that application of formaldehyde (3 gals of 37% to 100 gals of water) is helpful after crop removal. Spray the formaldehyde in a closed greenhouse with an airblast sprayer on a sunny day. The greenhouse should remain closed for at least 12 hours. Complete spray coverage is needed of all inner glass, pipes and walkways. Formaldehyde is an effective biocide that results in nearly complete kill of airborne fungal and bacterial spores, algae on pipes and some insects and mites. Disadvantages are that no plants can be present in the greenhouse range and that special application and safety equipment (including a respirator) to protect the applicator must be used.

Soil Management

Whether you steam or chemically treat your soil, the goals are the same: eradicate pests and then prevent their reentry. An important point to consider is that once soil is treated, enter the treated area as little as possible and use only pest-free implements to work the soil. It is often impossible to completely eradicate disease organisms. The result is untreated hot spots. Limit spread from such hot spots to the treated areas by working the soil as little as possible. Often it is possible to plant no-till or to work only that soil in which transplants are placed.

Perhaps the most important single item in a sanitary program is soil sterilization. However, the rigid practice of a single phase of sanitation and the neglect of others will not give satisfactory results. Because of its importance, soil sterilization is discussed separately.

Care and Planting of Transplants

Whether you produce your own transplants or purchase them from a reliable supplier, the important thing is **pest-free plants.** The earlier that plants become infested, the more severe the effect will be on yields. The most important time of pest exclusion is during the transplant stage. Clean hands, tools, pots and planting soil are fundamental steps in producing pest-free plants. If, in spite of all precautions, infested transplants are found, it is always beneficial to discard them before planting.

A primary consideration for growing healthy transplants is to have the plant house separate from the main growing house. There are two advantages: First, it is much easier to limit the activities of workers and ensure that they do not walk back and forth between old, infected plants and new, healthy plants. Second, a separate house helps prevent fungal spores, insects and mites on the old crop from flying, walking or being blown to the new, healthy transplants.

Only clean clothes, including shoes, trousers, shirt and hat, should be worn by persons who work in the plant house. The preferred method is to have all work in a plant house done by one person who does not enter the growing houses. In addition to clean clothes, workers' hands must be clean. Freeing hands of virus contamination requires long and hard scrubbing. Casual washing with soap and water is not effective. Only thorough washing with soap and running water will remove all danger of contamination.

All tools such as garden hoses, rakes, hoes, dibbles and shovels must be thoroughly scrubbed before being taken into a plant house. Do not use tools from the plant house in the growing house. If this is done, the cleaning process must be repeated before the tools are re-used in the plant house.

One last word of caution: growers should examine all practices from the standpoint of their possible effect on the introduction and spread of insects, mites, and disease organisms. It is impossible in this discussion to cover all practices applicable to all conditions. However, growers can, with a little thought, plug the loopholes.

Sanitation During the Crop

Skillful growers are able to reduce losses caused by pests to a minimum by careful adherence to the previously mentioned steps and by attention to the following guidelines: (1) constant attention to the development of pests and their identification and removal if warranted; (2) routine treatment of tools and walkways with a disinfectant (see disinfectant table); (3) establishment of foot baths and (4) elimination of weeds and debris bordering the greenhouse.

All tools must be cleaned before they are taken into the greenhouse in which the soil has been sterilized. Along with the use of clean tools, it is essential that workers wear fresh, laundered clothes after cleaning a greenhouse and before working with healthy plants in freshly sterilized soil. Also, before working with healthy plants, all workers should wash their hands thoroughly with soap and water. Dirty tools, dirty clothes and contaminated hands of workers can spread many virus diseases as well as soil-borne diseases such as wilts, nematodes and damping-off organisms. Often, dogs or cats are allowed to wander through greenhouses. Growers should be aware that these animals can carry pests on their feet or fur from infested to clean areas.

A clean strip around the outside of a greenhouse is equally important for both insect and disease control. Such a strip serves as a buffer to prevent tracking in soil-borne organisms during wet periods and helps to prevent pest-organisms from being blown into the greenhouse. Potatoes, tobacco, cucumbers, melons, other vine crops, spinach, celery and dahlias should not be grown close to a greenhouse because they can be sources of fungi and viruses, which may cause diseases.

Weed control within the greenhouse is very important and is a point often ignored by many growers. Many weeds harbor viruses, insects and mites and should not be allowed to grow in the greenhouse or within 150 feet of the greenhouse on the outside. Milkweed, lambsquarters, pigweed, pokeweed, plantain, dandelion, chick-

Disinfectants

There are several different types of disinfectants used to control plant disease organisms, some insects and mites. The choice of disinfectant depends on the pest and crop.

Disinfectant	Use	Disadvantages
Bleach (sodium hypochlorite, calcium hypochlorite) (5.25% diluted 1:9)	Surface disinfectant. Effective against small microbes such as viruses, bacteria and fungus spores. Surfaces should be visibly clean before they are wiped or dipped in solutions. Has good penetration activity.	No residual action; corrosive to iron. Solutions rapidly lose activity, especially in light or in presence of organic matter. Not effective in killing fungus sclerotia or other resting structures.
Formalin (37%, diluted 1:18)	General disinfectant for tools, flats and soil. Good keeping qualities. Has excellent penetration activity.	Fumes are toxic to people and plants. Porous materials like wood and soil must be kept damp until all fumes have dissipated, or plant damage may result. Not effective against viruses.
Phenols (Amphyl, Lysol, CM-19) Usually contain surfactants and alcohol (1-3 oz/5 gallons of water)	Surface disinfectant. Effective against bacteria and fungus spores. Solutions retain activity for some time.	Not effective against fungus sclerotia or viruses. Poor penetration. Rapidly broken down when in contact with organic matter.
Quaternary ammonium compounds (Physan-20) (1 oz/2 gallons water)	Surface disinfectant. Good algicide.	Not effective against viruses or fungus sclerotia. Very reactive and breaks down quickly on contact with air and organic matter. Poor penetration. Compounds should be used promptly after mixing.

weed, catnip and members of the nightshade family such as ground cherry, horse nettle and Jimson weed are among the most common offenders.

SOIL STERILIZATION

Soil "sterilization" is an expression used to denote disinfestation of the soil. The disinfesting agent may be either a chemical or heat. Sterilization implies the complete killing of all living entities and as such is a misnomer because the sterilization practices used are insufficient to kill all living organisms. Although it would be desirable to kill only the pathogenic organisms, the actual result is that some good as well as some pathogenic organisms are destroyed.

Heat is the only disinfesting agent that can be relied upon to destroy bacteria, fungi, nematodes, mites and insects. Some of the chemical disinfestants have specific uses and are discussed under the heading "soil fumigants."

Soil may be heated by several methods. The goal of all methods is to raise the soil temperature to a point and maintain it at that point for a sufficient period of time to ensure that all pathogenic organisms are destroyed. Fortunately, most pathogenic soil organisms are destroyed at relatively low temperatures.

Buried Tile

Soil sterilization by the buried tile method is by far the most widely used in Ohio and gives the best results. The chief disadvantage of the method is the cost of installation. However, once a permanent tile system is installed, it lasts for many years and requires less labor for its operation than other systems. The system is flexible. For example, clay pots in the plant houses may be placed on top of the soil beneath the sterilizaing cover and sterilized at the same time as the soil. Or pots may be filled with soil, placed under the cover and sterilized at the same time as the soil. Either of these methods works best when plants in the plant house are grown directly on the soil without benches.

A permanent buried tile system consists of rows of drain or perforated tiles laid with their centers 18 inches apart. They usually are laid so the tops of the tiles are about 10 inches below the surface of the soil. This is deep enough so that the tiles are not likely to be destroyed by tillage tools, yet shallow enough so that the soil can build up several inches before the tiles have to be relaid or soil removed. Some growers have installed plastic perforated tile such as that used in field drainage. This tile has a major advantage over clay tile in that installation costs are much reduced. Heat resistant tile must be used.

The tile lines are all connected at one end by elbows and tees. At the other end, these lines are connected to a header system. Frequently, a compound system is installed so that a series of tile lines extends each way from the header. Experience proves that it is unwise to attempt to extend tile lines farther than 50 feet from the header. If this distance is much greater than 50 feet, excessive condensation water collects and poor sterilization results.

The most satisfactory headers are made of steel. These are usually 2½- or 3-inch pipe. The pipe is either drilled for nipples, or nipples are welded onto the pipe. These nipples are spaced 18 inches apart. Such nipples are usually 8 inches long and are of ½-inch pipe. Tees, ¾ x ½ x ¾-inch, are screwed on the end of the nipples. In the center of the tee, pointing directly down the tile line, a ¼-inch hole is drilled. Patented tees are available for this purpose. Where 3-inch sterilizing tiles are used, a 4-inch tile at the header works best. One end of the tiles is filled with concrete, leaving holes large enough to slip over the nipples. Tiles are laid toward a header. A 3-inch tile will slip inside a 4-inch tile, making a sliding joint. This eliminates the need for cutting tile.

Two sizes of tile, 3-inch and 4-inch, are in common use. Both give good results. It is somewhat less expensive to use 3-inch tile; it often is difficult to obtain. Due to the smaller circumference of the tile, there is also less opportunity for steam to escape from the ends of the tiles into the soil. When sterilizing tiles are laid, they should be liberally covered with crushed stone or some other material that will not disintegrate. Tile should be laid either level or on a slight grade. A slight grade away from the header is preferred because condensation water will not collect at the header. In order to keep soil from becoming water-logged, a drain tile should be installed below the sterilizing tile at the end away from the header. The sterilizing tiles are usually laid in the bottom of a shovel-width ditch. Tiles must not be laid tightly together. Best results occur if 3/16 to 5/16 of an inch is left between tiles. When tiles become wet, they swell and expand, thus tending to close the space.

It is more expensive but more satisfactory to permanently connect the riser from the header directly to the sterilizing main. Then, when sterliizing, it is only necessary to open the valve and cover the soil. Covers over the soil are necessary to retain the steam and ensure thorough treatment on the surface. Unsterilized debris will remain in many places if a cover is not used. Many types of covers are available, such as black building paper, synthetic rubber sheets, polyethylene sheets or specially made sterilizing cloths. Sterilizing cloths are the most satisfactory but are considerably more expensive.

The length of time necessary to sterilize soil varies with the size of steam pipe leading to the sterilizing tile, the steam pressure in the sterilizing main and the type of soil to be sterilized.

The objective of soil sterilization is to heat the soil to or near the boiling point of water and then maintain it at that temperature for several hours. The pressure of the steam is relatively unimportant as long as at least 15-pounds-per-square-inch is maintained at the boiler. The important thing to consider is the amount of heat transferred into the soil. Research has shown that soil should be held at 180 degrees Fahrenheit for 4 hours. If it is possible to heat the soil to 180 degrees in one hour, then the sterilizing time would be 5 hours. On the other hand, if it takes 15 hours to heat the soil to 180 degrees, the sterilizing time is 19 hours.

The question frequently arises as to the size of the boiler needed to sterilize the soil. The correct answer is any size boiler that will develop 15 pounds of pressure. There is, however, a load limit for boilers. It has been found that with heavy soils, a good load for a boiler is 10 square feet of soil for each boiler horsepower. In light soils this may be increased to 15 square feet for each boiler horsepower.

Surface Steaming Method

Some growers sterilize their greenhouse vegetable soil by releasing steam through perforated pipe or porous hose under a plastic cover. This method is satisfactory for coarse, porous soils, but because steam moves upward through the soil about twice as easily as it moves downward or sideways, it is not generally considered as efficient as the buried tile method. On heavier or compacted soils, it is very difficult to force steam downward into soil to the required depth of 12 to 14 inches.

Bury the edges of the plastic cover 4 or 5 inches deep so that steam up to 6 or 7 pounds pressure can be confined. Higher pressures can cause blow outs. When moving the sheet from a steamed to an unsteamed area, avoid contamination of the steamed soil with unsterilized soil used to bury the edges of the plastic cover. As with the buried tile method, it is advisable to check the temperature accurately in several locations beneath the plastic, using specially-designed thermometers where the sensitive element is attached to a dial by several feet of cable.

After the soil is sterilized, it is essential to prevent it from being recontaminated. It is important for growers to remember that freshly-steamed soil is much more susceptible to recontamination than unsteamed soil, so extra precautions are needed. Some of the chief means of recontamination are using tillage tools in unsterilized soil and then in sterilized soil and leaving unsterilized soil on walks where workers tramp back and forth between sterilized plots and unsterilized plots.

Soil steaming may result in some undesirable effects. These include (a) excessive ammonia release, (b) manganese toxicity, (c) higher total salts level, and (d) destruction of organic matter. Leaching usually is necessary after steaming to eliminate some of these problems.

CHEMICAL SOIL FUMIGANTS

If a grower is unable to steam treat soil, he must consider treating with fumigant chemicals. Fumigants can be applied by the grower if he is licensed by the state to do so. However, because special equipment is required to inject fumigants into soil, many growers either rent fumigation rigs from dealers or have the fumigant applied by custom applicators. Fumigation is less costly than steaming. Unfortunately, the fumigants do not kill plant viruses and often are marginal in controlling pathogenic bacteria. They generally are satisfactory for the control of weeds, fungi, insects and nematodes.

The most common general-purpose soil fumigants in use in greenhouses are:

1. Methyl bromide — chloropicrin mixes: Applied as a gas under cover. Very broad biocide, and very hazardous to humans. Must be used only by experienced applicators with appropriate protective equipment. See label for details.
2. Vapam (Stauffer Chemical Company): A water soluble product, usually applied as a soil drench.
3. Vorlex (Nor-Am Agricultural Products): Usually injected into soil and sealed with water or plastic cover. Vorlex has a long residual in cold soils. This material should be applied only during warm soil temperatures and when the weather is warm to allow good ventilation. Work the soil until all traces of the fumigant are gone.

The fumes of chemical soil fumigants are very toxic and should not be inhaled. Applicators must use respirators (see labels for recommended equipment). Never allow these liquids to remain in contact with skin; wash them off immediately. If the liquids are accidently spilled on clothing, the clothes should be changed at once.

Do not use these materials when living plants are growing in the area because they are highly phytotoxic. Growers should take precautions that fumes do not travel through electrical conduits or steam or drain lines into adjacent houses.

For further information on fumigation techniques, see Ohio Cooperative Extension Service Leaflet-249.

SOILLESS GROWING SYSTEMS

There are several growing systems that do not use soil to produce cucumbers. Among these are the nutrient film technique (NFT), rockwool and peat bag culture. All have various horticultural advantages and disadvantages, but that is not the subject of this publication. From a disease standpoint, serious problems may occur with *Pythium* and possibly *Phytophthora* in those systems that recirculate the nutrient solution, favoring rapid reproduction and spread of these pathogens. Once these organisms get into such a system, the only practical way to eliminate them is by shutting it down, undertaking thorough sanitary procedures, and starting over. This is discussed in more detail in the section on "Pythium Wilt." This problem is less serious in non-recirculating systems such as peat bags and rockwool. A further advantage of rockwool is that sterilization between crops is possible.

Insects are no more likely to cause economic injury in these systems than in soil. However, the nutrient solutions used may promote alga growth, which is a food source for certain species of small flies, (Family Ephydridae) that sometimes can injure roots. This has been observed in the Netherlands on rockwool culture.

Thorough sanitary methods are extremely important in soilless culture and suggestions made above for soil production should be carefully considered.

MAJOR INSECT AND MITE PESTS GREENHOUSE CUCUMBERS

Several insect and mite pests consistently attack and damage greenhouse vegetable crops. The biology, damage potential and control of these pests are discussed in this section. As most growers know, there are few pesticides registered for use on greenhouse food crops. Of those that are registered, many may not be effective because of pesticide resistance by the pest. Therefore, it is important that you do everything possible to prevent an infestation from becoming established. As mentioned previously, these procedures include destruction of crop residues, thorough clean-up between crops, a crop-free period, avoiding bringing infested plants into the greenhouse and destruction of weeds inside and outside. Do not expect insecticides to work miracles. Help them with sanitation and by implementing cultural controls whenever possible.

Pests are discussed in detail so you can detect either the pest or its injury as soon as possible, hopefully avoiding a heavy build-up that would be extremely difficult to control. If in doubt about the identity of an insect or mite, have it identified. In most areas this is done by the Cooperative Extension Service. There may be a small fee for identification, but it is worth it. No specific pesticide recommendations are given in this Bulletin. Information on this subject can be obtained in Bulletin 517, published by the Ohio Cooperative Extension Service. However, alternatives to total reliance on conventional pesticides will be mentioned. Some of these alternatives are presently available, some are for the future, but growers should be aware that the future management of insects and mites will rely to a greater degree on these alternatives. Control programs may not be as simple but should be more reliable and reduce the constant problem of ineffective pesticides.

Remember, we seldom need to completely eradicate an insect or mite pest. This is because vegetable crops are able to tolerate a certain infestation level without losing production, except when the pest feeds directly on the fruit. Unfortunately, we do not know what the economic injury level is for most pests, but rather than elimination, growers should aim at keeping pests at low levels. To do this, plants need to be inspected frequently for the presence of pests and their injury. Both chemical and biological controls are more effective when infestations are detected early. The use of sticky yellow traps is useful in detecting populations of whiteflies, thrips, leafminers and winged aphids. For best results, traps should be used in combination with plant inspection.

Greenhouse Whitefly

The greenhouse whitefly, *Trialeurodes vaporariorum* has been a common and persistent pest of greenhouse crops for more than 80 years. Whiteflies are not true flies but are related to aphids and scale insects. Adults (Fig. 1) are pure white, have four powdery wings and are about 1/16-inch long. Most adults are found on the lower surfaces of the upper leaves, which they prefer for feeding and egg-laying. Females lay 150 or more stalked eggs, nearly always on undersides of leaves. Whiteflies lay about three times as many eggs on cucumber as on tomato. At first the eggs are creamy colored but before hatching turn dusky brown. At normal greenhouse temperatures, eggs hatch in about 10 days into tiny, white, oval nymphs or "crawlers" that move about the leaf for 1 to 2 days, searching for a suitable feeding site. Once a suitable site has been located, the crawler stops all movement and the legs lose their function for the remainder of the nymph's development. Whitefly nymphs pass through three instars and a "pupal" (transformation) stage before reaching adulthood. Generally, the egg to adult cycle is completed in fewer than 30 days. Adults live about 30 days and females lay 4 to 10 eggs per day, depending upon temperatures. There is some evidence that lower light intensities increase longevity and egg-laying on cucumber. This probably is related to changes in the plants rather than the whiteflies.

Both adults and nymphs pierce the foliage with their mouthparts and feed on plant fluids. Heavily infested leaves are smaller than normal. In addition to direct feeding injury, adults and older nymphs excrete large amounts of honeydew that can cover foliage and fruits. When relative humidity remains high for extended periods, a black sooty fungus begins to grow on the honeydew and can interfere with leaf photosynthesis and transpiration (Fig. 2). The number of whiteflies required for this problem to occur varies.

Extremely heavy whitefly populations can reduce yields. Probably, the extent of reduction depends on the stage of plant growth, whitefly populations, duration of infestation and environmental conditions in the greenhouse. To obtain maximum yields, these insects must be kept at relatively low levels during the growth of the crop.

A more recent problem has been the relationship between whiteflies and transmission of beet pseudo yellows virus (BPYV). Apparently, whiteflies are able to transmit BPYV in as little as 1 to 2 hours of feeding. See the discussion of BPYV in the disease section of this bulletin for further details. The fact that whiteflies are vectors of this pathogen, however, is an additional incentive to keep populations at minimal levels.

Control

Because of this insect's life cycle and the lack of registered systemic insecticides, a chemical control program must consist of frequent applications of short-residual materials. To reduce a well established infestation, applications need to be repeated at 3 to 4 day intervals for about a month. Coverage of lower leaf surfaces with foliar sprays is important but fumigants are more useful because leaf surface coverage is not necessary.

In addition to conventional insecticides, research and commercial growers' experience in Europe, Canada and elsewhere have shown the value of *Encarsia formosa*, a small parasitic wasp, in whitefly control. Hundreds of acres of greenhouse cucumbers in commercial production use this parasite. The adult parasites lay eggs in whitefly nymphs, and the resulting parasite larvae feed on the nymphs, killing them. If introduced properly (i.e., when whitefly populations are very low), whiteflies are kept at low levels throughout growth of the crop. Research has indicated that *Encarsia* can be used effectively in U.S. greenhouses as part of an integrated pest management system. However, unless the parasites are introduced at the first sign of whiteflies, control with parasites will not be successful.

As mentioned in the pathogen section, breaking the life cycle by an interruption of cropping is a useful and effective control technique for whiteflies (and other pests). This is especially true in preventing virus transmission and spread.

Leafminer

The leafminer, *Liriomyza trifolii* has become a severe pest of several greenhouse crops throughout Ohio. Infestations generally have been heaviest on tomato and chrysanthemum, but occasional heavy attacks have occurred on cucumber. This happens most often when tomatoes and cucumbers are grown together. To date, no obvious reduction in yields resulting from leafminer feeding has been noticed.

The biology of leafminers varies with the host plant (and variety), so it is difficult to generalize. However, the following information gives some idea of this pest's life cycle. Adults are small black flies with yellow markings (Fig. 3). They are most active on bright sunny days and often can be seen on upper leaf surfaces. The female punctures holes in upper leaf surfaces with her ovipositor. Eggs are laid in some of these holes, but most are used as feeding sites by both sexes, which feed on exuding plant fluids. These punctures or "stings"

(Continued page 10)

CUCUMBER INSECT PESTS


Fig. 1: White fly adult


Fig. 2: Sooty fungus


Fig. 3: Leafminer adult


Fig. 4: Leafminer injury


Fig. 5: Aphid adult and nymph


Fig. 6: Aphid injury

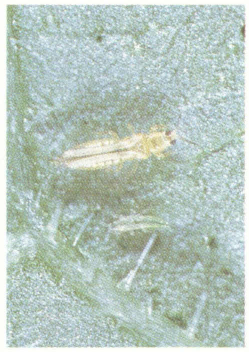
Fig. 7: Thrips adult and nymph

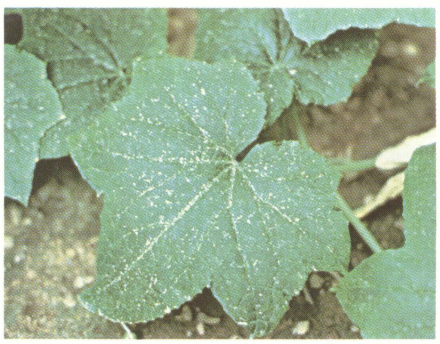
Fig. 8: Thrips injury


Fig. 9: Striped cucumber beetles


Fig. 10: Cabbage looper

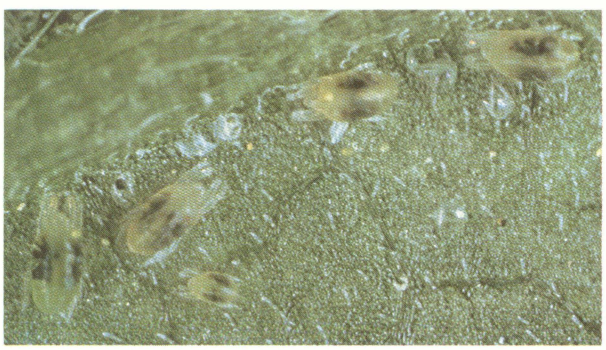
Fig. 11: Two-spotted spider mites

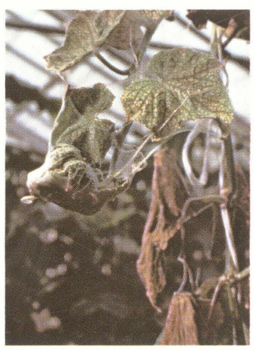
Fig. 12: Severe spider mite injury


Fig. 13. *Tyrophagous* mites

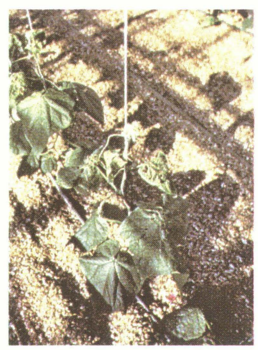
Fig. 14. *Tyrophagous* mite injury

CUCUMBER DISEASE SYMPTOMS

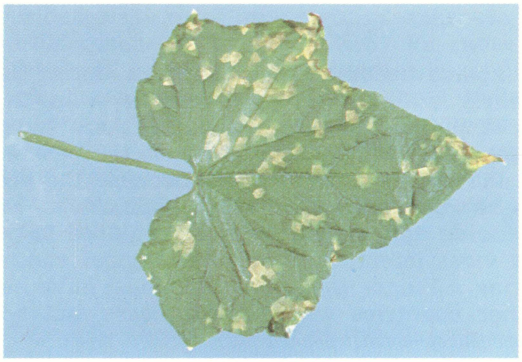
Fig. 15: Downy mildew


Fig. 16: Downy mildew fungus on undersides of leaves


Fig. 17: Powdery mildew


Fig. 18: V-shaped gummy stem blight lesions


Fig. 19: Gummy stem blight lesion at node


Fig. 20: Gummy stem blight on fruit


Fig. 21: Section through gummy stem blight fruit lesion


Fig. 22: Botrytis stem canker with grey fungus growth

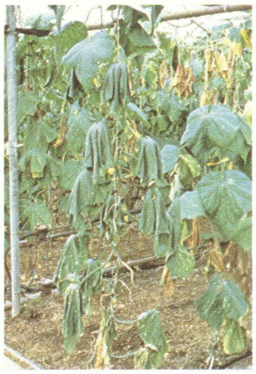
Fig. 23: Bacterial wilt


Fig. 24: Root knot nematode


Fig. 25: Cucumber Mosaic Virus—foliar mosaic

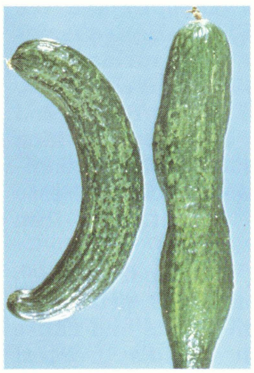
Fig. 26: Cucumber Mosaic Virus—fruit distortion


Fig. 27: Beet Pseudoyellows Virus—advanced symptoms

are a good indicator of a potential infestation. Each female is capable of laying several hundred eggs during her lifespan at the rate of 30 to 40 per day, so uncontrolled populations can increase rapidly.

Eggs hatch in about 5 days, and the legless larvae immediately begin to feed between upper and lower leaf surfaces. Leafmines gradually increase in size and become quite serpentine (Fig. 4). Many larvae can develop in a single leaf. After feeding for 5 to 10 days, mature larvae exit the mines by cutting openings in the upper leaf surface and dropping to the soil surface to form the pupal (transformation) stage. Larvae attempt to move underneath some object during this process. Some pupae remain on the upper leaf surface and complete the transformation without dropping from plants. The pupal stage lasts from 5 to 40 days, depending on day length and temperature. When adults emerge, mating occurs within 1 to 2 days and egg-laying begins soon after. A common feature of leafminer populations is for them to remain at relatively low levels during the winter and spring months but have a population "explosion" during May and June. The low winter population levels may be due to several factors, including lower temperature, reduced sunlight and shorter days. This then might produce plants less favorable for leafminer reproduction and survival.

Control

The best way to avoid problems with leafminers is prevention because effective control with presently registered pesticides is nearly impossible. Cultural methods such as interruption of cropping and thorough clean-up and destruction of crop residues are effective in reducing leafminer populations. Crop interruption will disrupt the life cycle and prevent development of extremely high populations such as those that have been observed on continuous chrysanthemum crops.

Leafminers are heavily parasitized out of doors, but routine insecticide use in greenhouses prevents these parasites from becoming established. Work is in progress in several locations to determine the potential of parasites for leafminer control on greenhouse crops. Several species of parasitic wasps have been collected from leafminers, reared and introduced onto leafminer-infested plantings in greenhouses with varying degrees of success. The next few years should yield reliable parasite species and introduction techniques. There is some evidence that parasites will enter a greenhouse if routine insecticide applications are stopped, although supplemental introductions probably will be required, especially early in the crop.

Aphids

Two aphid species commonly occur on greenhouse cucumbers: the melon aphid (*Aphis gossypii*) and the green peach aphid (*Myzus persicae*) (Fig. 5). Both species are almost always found on lower leaf surfaces. In greenhouses, all aphids are females that give birth to living young; hence, no egg or pupal stages to contend with. Each female can produce about 50 offspring which begin reproducing in 7-10 days. Under certain conditions, aphids produce winged adults that can fly into greenhouses from outdoors or disperse within greenhouses.

Aphids feed with piercing-sucking mouthparts, much like whiteflies, removing plant fluids and producing honeydew. High populations can stunt plants and cause severe leaf deformity (Fig. 6), but aphid's greatest threat to cucumbers are as vectors of cucumber mosaic virus (CMV). The melon aphid is most often associated with this virus. See the discussion of CMV in the disease section of this bulletin for more information on this disease.

Control

Usually, aphids become most abundant during late summer—early autumn, after dispersing from their summer host plants outdoors. Avoiding them by not growing cucumbers during this season is the best way to prevent the problems with CMV, because the virus is likely to be abundant in the aphid populations. Frequent insecticide applications may be required to prevent heavy virus infection. Several biological controls (one involving a fungus that attacks aphids) have been used in other countries with some success, but none are commercially available in the U.S.

Thrips

Probably the most common thrips species on greenhouse cucumber in Ohio is the onion thrips, *Thrips tabaci*. In other parts of North America, other species such as the western flower thrips, *Frankliniella occidentalis,* may occur. These pest are found nearly worldwide and feeds on many host plants.

Thrips (Fig. 7) are very small, narrow insects about 1 mm long. The adults are winged and able to fly. Thrips overwinter in crops such as clover, wheat or alfalfa and move to vegetable crops in late spring to early summer. There are several generations each year. Thrips can easily fly into greenhouses through open ventilators and become established on cucumbers. Yellow or white sticky traps are useful in monitoring for the presence of thrips.

Thrips feed by rasping plant tissues with their mouthparts. Damage symptoms on leaves include areas of whitish or silvery specks, streaks or "windows" in the foliage (Fig. 8).

The generalized life cycle is as follows: Eggs are laid in slits cut in leaves. Each female can lay about 60 eggs. Following egg hatch, there are two immature stages followed by "prepupal" and "pupal" stages. Both of these transformation stages occur in the soil. The entire life cycle can be completed in 10 to 30 days, depending on environmental conditions. Warm temperatures and low humidities are favorable for thrips development.

Control

Because thrips can appear in large numbers quite suddenly by flying from nearby infested crops, a good monitoring system will be very helpful regardless of control measures selected. Scouting plants for injury symptoms, using sticky traps, or beating leaves over a white paper or pan are useful techniques. At present, insecticides are used for control, but there are possibilities for using a mite that is a thrips predator. Thrips will continue feeding throughout the winter, so interruption of cropping will be helpful in lowering thrips populations. A control method that has been successful in Europe is to apply polybutenes plus an insecticide to the soil or plastic below plants to kill thrips as they drop from the plant. Apparently, the sticky polybutenes expose the thrips to a lethal dose of the pesticide.

Cucumber Beetles

Two species of cucumber beetle, the striped (*Acalymma vittatum*) (Fig. 9) and spotted (*Diabrotica un-*

decimpunctata howardi) are very important pests of cucumbers in the field and greenhouse. These insects are important as vectors of the organism causing bacterial wilt. Of the two species, the striped beetle is considered the most important as a disease vector. See the discussion of "bacterial wilt" for more details.

Outdoors, both species overwinter as adults in weeds, trash, fence rows, etc. They become active early in the spring. The wilt organisms also overwinter with the beetles, so transmission can occur at any time. There are two generations per year in Ohio, with adults most commonly moving into greenhouses from early to mid-summer.

Control

The only known control of this disease is to prevent the beetles from entering the greenhouse, coupled with an intensive pest control program. Not growing cucumbers during the major activity periods is the best method. Prevention of entry by screening doors, vents and/or elimination of susceptible host plants in the vicinity of the greenhouse (although adults apparently can fly long distances) are other possibilities. Insecticides for control need to be used frequently (at least once per week), which can result in plant injury and subsequent yield loss. As a guide, even with the most intensive program for beetle management on outdoor cucumbers (where registered insecticides are available), a 5 to 8 percent loss due to bacterial wilt is common. There is no known biological control for cucumber beetles.

Cabbage Looper

The cabbage looper, *Tricoplusia ni*, can become a problem on greenhouse cucumbers if plants are small, or if fruits are present. Young plants can be defoliated and fruits often are scarred by their feeding, making them unsalable. Adults are grayish-brown moths with a wingspan of about 1½ inch. Forewings are a mottled dark brown and have small silvery spots near the center. Moths generally fly into greenhouses during late summer and autumn. Once inside, their life cycle continues throughout the winter, as long as suitable host plant material is present.

Females scatter their eggs over the foliage at night. Eggs hatch into tiny pale green caterpillars. When very young, caterpillars do not completely chew through the leaf but only scrape a portion of the cell layers. However, larvae grow rapidly. During their development period of about 2 weeks, they can destroy large amounts of plant tissue. *T. ni* caterpillars are called loopers because of their method of locomotion (Fig. 10). They draw the posterior end of the body up nearly to the front legs, forming a loop, before moving the front leg forward. They are often difficult to see because of their coloration and habit of feeding on undersides of foliage, but an infestation can be recognized by the presence of fecal pellets on the foliage and irregular holes in the leaves.

Control

Early detection of a cabbage looper infestation is important. The larvae generally are easier to kill with insecticides when small, and resulting foliage and fruit damage is minimized. An excellent control procedure is to use one of the *Bacillus thuringiensis* formulations. These microbial pesticides are effective in killing loopers, yet are harmless to other parasites and predators. Usually one application is sufficient.

Two-Spotted Spider Mites

Two-spotted spider mites, *Tetranychus urticae*, although not insects, are closely related and are severe pests of greenhouse crops throughout the world. Spider mites are particularly troublesome on greenhouse cucumber because it is a favored host plant.

Spider mites are extremely small (1/50 inch) and wingless and usually feed on lower leaf surfaces (Fig. 11). Feeding damage is characteristic, with the upper surface taking on a speckled appearance. During heavy infestations, much webbing is produced, leaves dry up and plants may be killed (Fig. 12).

Each female produces about 100 eggs, which normally hatch within 4 to 5 days. The entire egg to adult cycle can be completed in 10 days or less, and populations can increase most rapidly during warm, dry weather. Also, a large number of mites may overwinter in the greenhouse structure. In Ohio, spider mites seem to go into hibernation in November and become active again in February-March. The hibernating forms are easily recognized by their bright red color. However, some mites remain active throughout the year.

Infestations often are localized, sometimes confined to only a few plants, but mites can easily be carried around the greenhouse on clothing, tools, etc. Infestations may begin on lower leaves, but the heaviest damage usually occurs near the tops of plants. Adult females tend to move upward, and the warmer temperatures in these locations are favorable for mite reproduction.

Control

Early detection and prompt response, whether with chemical or biological controls, is important. The leaves of cucumbers grow at an angle that makes spray coverage of lower leaf surfaces difficult. A predatory mite, *Phytosieulus persimilis*, has been used with good success for spider mite control in many areas of the world. Introduction of these predators when spider mite numbers are low is crucial to their success. One drawback to using *P. persimilis* is that they are less effective at high temperatures. This may limit their usefulness during warm, sunny weather conditions. Another problem is that the predators are generally very sensitive to many pesticides (including fungicides). Efforts are being made to register a miticide which kills spider mites, yet is not harmful to the predator. Some suppliers are distributing predators that are resistant to some pesticides. Also, other predators are being investigated which may be more effective at high temperatures.

Tyrophagous Mites

Members of this mite group can be found in almost any situation throughout the world but are rarely of economic importance. However, tyrophagous mites of various species (in Ohio, the species is *Tyrophagous neiswanderi*) have been found damaging the foliage of cucumbers in Ohio on several occasions (Fig. 13). Other members of this genus have been reported from similar situations in other parts of the U.S. and Europe. Sometimes the injury is so severe that plants become stunted, leaves fail to form properly, or tops of plants are killed (Fig. 14).

The mites are apparently introduced on straw, manure or peanut hull mulch. The warm, moist environment created by the mulch and irrigation seems favorable for population development, and huge populations are sometimes produced. High humidity (above 75%) in the greenhouse also favors mite survival. No detailed life history studies of *T. neiswanderi* have been conducted, but only adults and eggs are usually found on plants. The eggs or nymphs probably drop off the leaves and develop in the mulch area before again moving onto plant tissue.

Control

Control of these mites can be difficult. Sterilization of soil and mulching materials prior to placing it in the greenhouse will destroy mites, and probably is the most effective method. Miticides and other chemicals have generally not been very effective at rates safe to plants. In one greenhouse, a band of petroleum jelly placed near the base of each plant prevented the mites from moving back onto the leaves.

MAJOR DISEASES OF GREENHOUSE CUCUMBER

SEEDLING DISEASES

Damping-off

Two problems often encountered by growers are damping-off due to parasitic organisms and a similar type of trouble caused by excessive fertilizer applied to soil used in raising seedlings. The symptoms of both are somewhat similar and frequently can be distinguished only by testing for soluble fertilizer salts and by microscopic and cultural methods to determine whether a parasitic organism is present. Typical damping-off produces a constricted lesion at the soil level without affecting the healthy appearance of the roots and tops. Typical fertilizer injury produces brown roots, healthy but stunted tops and no weakness at the soil level. When both damping-off and fertilizer injury are severe, symptoms overlap and the two diseases cannot be distinguished except by laboratory methods.

The most common early sign of parasitic damping-off is the non- or sporadic-emergence of seedlings. Later, seedlings begin to topple over. In a seed bed, these areas generally enlarge from a central point or points, and under favorable conditions for disease development, the entire bed may be affected.

Pythium

The symptoms of damping-off caused by *Pythium* spp. are of two distinct types. The one most commonly known is that in which the hypocotyl of the seedling, after emergence, becomes water-soaked and discolored at the soil surface. This is known as post-emergence damping off. These plants fall over, quickly wither and die. This also can happen to uninfected transplants soon after planting into infested soil.

The other general symptoms of damping-off are poor stands or stunting of plants. In this case pre-emergence damping-off occurs because the hypocotyl is attacked before it emerges from the soil. The first symptoms are small, brown, water-soaked lesions that, under favorable conditions, affect the entire root system, frequently killing the seedling. If seedlings do emerge, the hypocotyls and roots remain diseased. The plants are stunted, abnormally dark green and and the cotyledons roll downward. The latter type of attack is frequently very destructive because such diseased plants, unnoticed by the grower, are transplanted and may die later. In any case, they are never very productive.

Rhizoctonia

There are three general symptoms of damping-off caused by *Rhizoctonia solani*. Two of these closely resemble symptoms caused by *Pythium* spp., namely, the toppling over of seedlings and the general diseased condition of the hypocotyl and roots. The principal symptom difference is a dry, shriveled, rather than water-soaked lesion. The third symptom is a deformation of the cotyledons. Seedlings stunted by either *R. solani* or *Pythium* sp. often have an abnormally deep green color.

Control

Absolute sanitation to exclude the pathogens is necessary to avoid damping-off. Soil mixes should be thoroughly steam-disinfested or sterile soilless mixes used for germination and transplant production. Seed containers, pots and benches also should be disinfested with steam or chemicals. If damping-off is a persistant problem, investigation of the water source and debris disposal should be made to check for sources of *Pythium* contamination. Pond or other surface water should not be used for irrigation. Seedlings should be grown under optimal conditions of warmth, light and nutrition. Adequate bottom heat is essential. Do not place seedlings flat on ground, but place on benches with good aeration. Avoid overwatering and cold soil. Cold water (below 55 °F) should be warmed before using. If damping-off is found, all seedlings from an affected tray should be discarded. If *Pythium* is the causal agent, a soil drench fungicide may be useful.

FOLIAGE DISEASES

Downy Mildew

The casual fungus, *Pseudoperonospora cubensis,* can infect most members of the cucurbit family such as squash and melons. Because it is an obligate parasite on these hosts, it cannot survive between crops within the greenhouse. It is usually a problem only in fall crop cucumbers where spores blow into the greenhouse from outside-grown plants and is more prevalent in plastic houses with inadequate ventilation.

Symptoms on leaves begin as pale yellowish spots. These quickly enlarge to angular, bright yellow lesions that turn brown as the tissues die (Fig. 15). Under moist conditions, a purplish fungus growth will appear on the undersides of the lesions (Fig. 16). Extensive infections can kill the leaves and stunt growth of the plant. Fruit generally are not infected but will be of poor quality.

Control

Downy mildew is favored by high humidity and moisture on the leaves. In plastic houses and poorly-sited glasshouses, ventilation can be considerably improved by blowing air through plastic ducts. Overhead irrigation should be avoided and adequate ventilation provided. Outside sources of downy mildew should be controlled by avoiding cultivation of cucumber, melons and other cucurbits in the vicinity of greenhouses. If the disease becomes established, application of fungicides may be necessary.

Powdery mildew

Powdery mildew is first seen as small, discrete colonies composed of fine, white threads spreading across upper surfaces of infected leaves (Fig. 17). These colonies coalesce and the leaves eventually become covered with a white, talcum-like growth of spores that fall off when a leaf is tapped. In severe infections, leaves will yellow, wither and die, sometimes leaving "islands" of green tissue immediately surrounding infected areas. Petioles, stems and rarely fruit also will become infected. Even though fruit is not usually infected, damage often occurs due to hastened maturity with consequent poor quality and sunburning from loss of foliage.

The two fungi known to cause cucurbit powdery mildew, *Sphaerotheca fuliginea* and *Erysiphe cichoracearum* have been found on a wide range of host plants. Powdery mildew fungi thrive under relatively dry conditions, moderate temperatures, low light, high fertility and succulent plant growth. Unlike bacteria and many fungi, free moisture on leaf surfaces actually inhibits infection by these pathogens. Powdery mildew fungi are obligate parasites and survive the winter outside as dormant mycelium on perennial plants or are carried north on air currents as spores from warmer areas further south. In greenhouses, it is most severe in the fall crop where it comes in from late summer infections outdoors. Spores are formed abundantly on leaf surfaces and can be carried throughout the greenhouse on air currents, often resulting in rapid and severe epidemics. Mature foliage is most readily infected, with very young leaves being nearly immune.

Control

To control powdery mildew, avoid excessive succulence, overcrowding, shading, overwatering or excess fertilization. If possible, delay seeding until outside vegetation is killed by frost to prevent infection from outside sources. Avoid making new cucumber plantings in the vicinity of older infected plantings. Use good sanitation practices and eliminate weeds and trash piles. Avoid production of other susceptible crops and ornamentals that will harbor the fungi and spread them to new plantings. Routine applications of fungicides may be necessary. A few European seedless cucumber cultivars have a high degree of tolerance to powdery mildew.

Gummy stem blight

This disease, also called black stem rot, is caused by the fungus *Didymella bryoniae* (formerly called *Mycosphaerella melonis*). It attacks all parts of the cucumber plant and can cause extensive damage. Symptoms are: **Leaves** — Conspicuous V-shaped, yellowish-brown lesions beginning at leaf edges (often at leaf points) and extending back into the leaf blade (Fig. 18). These enlarge rapidly, coalesce and can cause curling, shriveling and eventual death of the entire leaf. Symptoms can be confused with leaf scorch caused by excess soluble salts or some pesticide burns. **Stems** — Light brown to brownish-black lesions develop at nodes, especially at pruning wounds (Fig. 19). Close inspection with a hand lens should reveal small black fruiting bodies (pycnidia and perithecia) of the fungus. Near the soil line, lesions may crack and produce an amber-colored gummy ooze that gives the disease its name. **Fruit** — Greyish green, watersoaked lesions usually beginning at the blossom end of immature fruit (Fig. 20). Fruit lesions are firm and usually are dark brown to black when cut open (Fig. 21). Occasionally lesions develop on the sides of fruit causing the fruit to hook as it grows. Infection of very small fruit can cause complete abortion.

Control

The causal fungus survives on infested debris on or in soil and may be introduced on seed, although this is unlikely if seed have been heat-treated for virus control. A high level of sanitation is necessary to control gummy stem blight beginning with steam disinfestation of soil. Elimination of plant debris inside the greenhouse as well as outside trash piles is necessary because they may be sources of millions of spores. Do not allow prunings and overripe fruit to lay on the soil beneath the crop. Overhead irrigation will favor the disease, as will inadequate ventilation. It can be spread mechanically on pruning tools or other machinery. Low night temperatures should be avoided, as this may cause water droplets to exude from leaf points and condensation to form on leaves, favoring disease development. Complete control may require routine application of protectant fungicides. Post-harvest fruit rots can be controlled by avoiding fruit wounding during harvest and storing fruit at 55 degrees F.

STEM DISEASES

Botrytis Grey Mold and Stem Canker

Botrytis cinerea is primarily a wound pathogen and infects senescent tissue. On cucumbers, infection usually occurs at pruning wounds resulting from the removal of fruit, laterals and leaves. The lesions are usually light tan and firm with distinct edges and may be covered with powdery masses of grey spores under humid conditions (Fig. 22). Stem lesions may enlarge sufficiently to girdle the plant and kill it in severe cases. Young fruit may be infected through the senescing blossom, resulting in abortion. Mature fruit are not likely to become infected unless the withered flower remains attached.

Control

Botrytis survives and sporulates well on senescent or dead tissues of most plants, so as in the case of gummy stem blight, removal of plant debris following pruning is essential. Refuse dumps should not be located in the vicinity of greenhouses. Infection is favored by high humidity and thus by overhead irrigation, inadequate ventilation, close plant spacing and excessive nitrogen fertilization. Early application of mulches close to the bases of plants may favor *Botrytis* infection and delay warming of the soil. Cool soils and warm moist air provides ideal conditions for this disease. Although fungicide applications may become necessary, this disease can be controlled by careful sanitation, proper fertilization, adequate ventilation and maintenance of night temperatures above 60 degrees F.

Sclerotinia white mold

This disease, caused by *Sclerotinia sclerotiorum*, has been seen on greenhouse tomatoes in Ohio but not on cucumbers. It has been a minor problem to cucumber growers elsewhere. Like *Botrytis*, infection usually occurs in areas of dead or dying tissue and produces wet, brown lesions. After a few days, a white, fluffy fungal growth appears and envelopes the stem, resulting in a watery rot. The fungus forms hard black, irregular shaped bodies called sclerotia in the center of infected stems. These structures may be up to ¼ inch in diameter and function as survival structures for the fungus. They can germinate in soil and infect stems directly or form spores that become airborne.

Control

Steam disinfestation of ground beds usually will eliminate this disease. Cultural recommendations for control of Botrytis stem canker also are helpful for white mold control.

ROOT DISEASES AND WILTS

Black root rot

This disease, caused by the fungus *Phomopsis sclerotioides*, has not been identified in Ohio but has occurred in Ontario, Canada, and is well known in Europe. Infected cucumber plants usually show reduced growth about a month after planting and may wilt suddenly at first fruiting without any marked leaf symptoms. Examination of root systems will usually show blackened feeder roots below ground and excessive rooting above the soil under the mulch. A diagnostic sign is that under a hand lens fine infected roots appear to have a mosaic or checkerboard pattern of black specks (sclerotia of the fungus).

Control

Black root rot is a disease of cold, wet soils. It can be well controlled only by steam disinfestation of the soil. Chemical fumigation is not very effective. Good sanitation within the greenhouse is essential to avoid reinfestation of steamed soil. Delaying application of mulch until soils have warmed to 70 degrees F is desirable. Plants should not be irrigated with cold water. If plants become infected, removing old mulch material and mounding clean soil around the stem base above a node to stimulate adventitious root production may be helpful.

Bacterial wilts

A number of bacteria have been associated with a sudden wilt of cucumber. This often occurs in sunny weather when the plants are in full fruit. One or a few leaves on infected plants may wilt first and become dull green, but often the entire plant wilts with little warning (Fig. 23). This disease may be caused by *Erwinia tracheiphila*, a bacterium that can live in the bodies of the striped (Fig. 9) and 12-spotted cucumber beetles. Bacteria are introduced into plants as the yellow and black beetles feed on leaves and stems or from contaminated beetle feces in contact with wounds. Bacteria reproduce in the plants' water-conducting vessels, producing gums that interfere with water transport.

Sometimes, if an affected stem is cut off near the ground, the sap may be milky in appearance or sticky and if touched with the finger, it will string out up to half an inch. This is a helpful test in diagnosis if present, but cannot be depended upon for positive identification. The beetles and bacteria are so intimately related that controlling the beetles will control infection by these bacteria. Once infection has occurred, however, no control is possible and wilting plants should be removed. The disease is not seed-borne.

In Florida, a similar wilt has been reported to be caused by *Erwinia chrysanthemi*. Lesions are near the soil line or associated with pruning wounds and bacterial ooze is frequently found exuding from them. Most infected plants collapse 1 to 2 days after initial lesions are noticed and the stems become soft. Little more is known about this disease.

Control

The only practical control measure for bacterial wilt is to control the beetle vector. Greenhouse growers should be aware that only a few beetles could cause substantial damage. The beetles are easily killed with insecticides, but damage may have already occurred by then. In fall crops, it is essential that outdoor gardens with cucumbers, melons or squash not be located anywhere near greenhouses. These beetles can fly long distances, however, and if persistant problems occur, it may be necessary to screen vent openings. In areas with high beetle populations, it may be necessary to delay planting cucumbers until outside vegetation is killed by frost.

Pythium wilt

In soil-bed culture, *Pythium* has primarily been a problem only on seedlings, causing damping-off in improperly disinfested media or in cold, wet soils. Use of hydroponic production systems, however, favors the development of *Pythium* on mature plants. In contrast with soil culture, where mature plants are relatively resistant, Pythium damage in hydroponic systems can be quite severe because the entire root system is exposed to the pathogen.

Pythium is a water mold and naturally adapted to a semi-aquatic environment. It has swimming spores that require free water to live and infect. If introduced into the recirculating nutrient solution of a hydroponic system, it can quickly spread throughout the entire crop and infect root systems as they are bathed by the infested solution. Infected root systems develop a yellowish-tan to brown color and the smaller roots become soft or even mushy. At this point, plants usually collapse with an irreversible wilt.

Control

Control of *Pythium* wilt in hydroponic systems is difficult. Exclusion of the pathogen is essential. Growers must avoid the introduction of soil particles, where *Pythium* spores are extremely common, into hydroponic systems. Extreme sanitation procedures may be necessary to prevent soil introduction on shoes, clothes or hands (under fingernails) of workers, on tools, or blowing in through vents. Research in North Carolina has shown that an infected transplant introduced into a hydroponic system can spread *Pythium* to other plants in less than 1 week. Extreme care must be taken in the raising of disease-free transplants.

If, despite all efforts, *Pythium* wilt develops, all infected plants and root systems should be removed and as much of the crop as possible salvaged. After the crop is completely removed, the tanks and trays should be drained, the entire greenhouse and all equipment disinfested and a disinfectant chlorine bleach solution should be pumped through the entire system for 2 to 3 hours, followed by complete rinsing. If *Pythium* problems persist, the water source should be checked for possible contamination. Use of a modified hydroponic system such as polyethylene bag culture where individual plants are separated and nutrient solution is not recirculated will greatly lessen the risk of this disease, although nutrient tanks must be carefully protected against introduction of soil particles.

Root knot nematode

Before the introduction of satisfactory methods of soil sterilization, nematodes were the cause of one of the most serious maladies of greenhouse crops. Nematodes are actually minute worms that live in soil and feed on plant roots. The first symptom of damage from root-knot nematodes is usually a stunting and wilting of the plant. When diseased plants are removed from the soil, extensive gall formation, or irregular swellings of the root, can be seen easily (Fig. 24). Gall formation is brought about by the presence of nematodes within the tissues which induce normal cells to multiply abnormally.

The male nematode is too small to be seen with the naked eye. The females, when filled with egg masses, can be seen. They appear as barely visible pear-shaped, glistening, whitish bodies, measuring slightly less than one millimeter in diameter. They may be seen with the naked eye in a root gall, if the tissue has been teased or pulled apart.

Control

Once nematodes become established in a soil, they are difficult to eradicate completely. They can, however, be satisfactorily controlled by steam disinfestation. The buried tile method is by far the most satisfactory. Resistance to nematodes is not available in commercial greenhouse cucumber cultivars.

VIRUS DISEASES

Cucumber mosaic virus (CMV)

This disease can be a serious problem for greenhouse cucumbers, especially when planted in late summer when aphids are abundant outside. Plants of all ages are susceptible and develop a striking, leaf mottling or mosaic pattern accompanied by some distortion (Fig. 25). Unlike nutritional disorders, the symptoms are scattered randomly across leaves with no veinal association. It is especially prominant in young, partially-expanded leaves. The disease may cause reduced flowering and distorted fruit covered with pale green blotches (Fig. 26). In extreme cases, sudden wilt and death may occur.

CMV is a very common virus with an extremely wide host range among crop plants (most cucurbits, tomato, spinach, celery, tobacco, bean) and many ornamentals and common weeds (chickweed, lambsquarters, pigweed). It is readily transmitted by aphids, which are the most likely source of infection for greenhouse crops. Once plants are infected, the virus quickly becomes systemic and then can be transmitted from plant to plant mechanically by workers, on tools, etc. Although seed transmission in cucumber has been reported, it is rare and not a likely mode of introduction. CMV does not survive well in soil or dead plant debris.

Control

Control of CMV depends primarily on avoiding introduction of the virus from outside sources via aphids. For this reason, cucumbers are not planted in regions of high aphid populations until after frost has killed outside vegetation. Strict aphid control with insecticides and good sanitation practices are necessary. Hands, tools and clothing should be washed frequently, especially, if used outside. If a few diseased plants are found, they should be carefully uprooted, put into plastic bags and removed from the greenhouse without touching other plants. Most cultivars of European seedless cucumbers are highly susceptible to CMV but a few tolerant cultivars are available.

Beet Pseudoyellows virus (BPYV)

This disease only recently was identified in Ohio. It was reported previously from California, The Netherlands and Japan on greenhouse cucumber. In infected plants, symptoms begin on older leaves and slowly progress up the stem. Newly developing leaves are generally symptomless. Symptoms begin as tiny, light green spots about 1/16 inch in diameter scattered at random across healthy-appearing leaves (cover photo). More of these soon develop, to produce a general stippling pattern. This pattern intensifies as the lesions become more chlorotic and blotches of dark green tissue delimited by small veins stand out (cover photo).

Leaves, then, become generally chlorotic with remaining green areas of tissue associated with major veins. Older leaves finally develop an extreme interveinal chlorosis with dark green veins and tend to curl downward (Fig. 27). Diseased plants become unthrifty and fruit production drops as symptoms progress up the plant. No obvious fruit symptoms are associated with BPYV, although some fruit abortion seems to occur in severe cases. Although some nutritional disorders can cause similar chlorotic symptoms on older leaves, the early stages of symptom development are diagnostic.

BPYV is transmitted only by the common greenhouse whitefly. It is not transmitted mechanically by workers or on tools and there is no evidence for seed transmission. The disease has a wide host range of crops (sugar beet, spinach, many cucurbits, lettuce, endive, carrot, tobacco), ornamentals (geranium, marigold, zinnia) and many common weeds (lamb's quarters, dandelion, shepherd's purse, thistle, nightshade, nettle). Tomato and radish are not susceptible.

Control

Control of BPYV is limited to control of the whitefly vector. Experience in Ohio indicates a relatively small whitefly population can infect an entire crop. If cucumbers are cropped year around, it is very difficult to break the cycle. Because infected whiteflies lose their ability to transmit BPYV within one week after removal of all susceptible host plants, a complete break in cropping along with removal of all plant material (including weeds) coupled with fumigation for whiteflies should eliminate the disease.

Introduction of BPYV is most likely on infected whiteflies from outside the greenhouse. It is essential to eliminate weeds within the greenhouse and avoid whiteflies from outside sources. Good outside weed control near the greenhouse is also essential to eliminate reservoirs of the virus for reintroduction.